Sustainable Livestock Production

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Before we start, just a few questions for you…

…capture the QR code and let's get started!

PROGRAM OF THE COURSE

Unit 1 - Overview of livestock productions
Comparison between intensive, extensive and organic production systems.
Species, breed and genotype, products (milk, meat, eggs, fish, insects as food), genetic selection, feeding, reproduction, housing, animal welfare, production efficiency.

Unit 2 - Quality of livestock products
Chemical composition of animal products (milk, meat, eggs, insects as food). Nutritional and nutraceutical properties of animal products. Factors affecting quality of primary livestock products (species, breed, genotype, nutrition, farm management, health status, climate conditions). Zoonosis caused by pathogens originating from products of animal origin will be treated.

Unit 3 - Environmental implications of livestock systems
Overview of the pollutants released in environment (air, soil and water) and natural resources depletion associated to livestock production systems. Contribution of livestock production to different environmental impacts, with specific regard to Greenhouse Gas emissions (GHG).

Unit 4 - Sustainability of animal productions
Significance of livestock productions in global food demand (feed the earth). Basic concepts of environment, biodiversity, and sustainability. Practices that might contribute to improve environmental sustainability in livestock production systems (genetic selection, nutrition, health, manure and water management). Environmental evaluation of products of animal origin. Main aspects of Life Cycle Assessment (LCA). Concepts and procedures to calculate carbon and water footprint related to livestock food products. Environmental certifications and ecological labeling of food of animal origin.

Unit 5 – New trends in sustainable animal production
Precision livestock farming (PLF) for production optimization and quality improvement of food products. Development of protocols for the production of "cultured meat" and "synthetic milk".

Unit 6 - Characterization of macromolecules in foods of animal origin
Methodological approaches for the analysis of proteins and fatty acids in animal products.

Learning materials:
Lesson notes, scientific articles, documentaries specifically indicated by the teacher.

UNIT 1

Overview of livestock productions

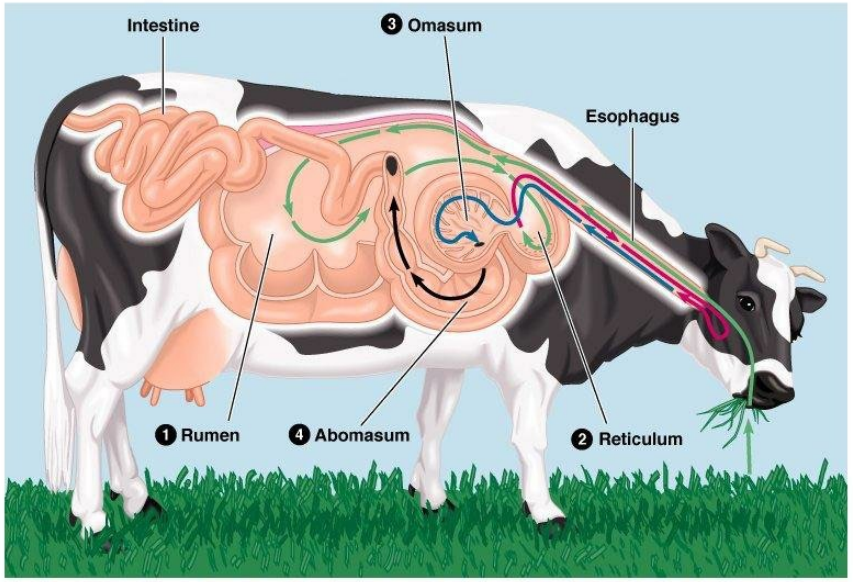
Farming animals for food

- ✓ Ruminants: cattle, sheep, goat, buffalo
- ✓ Monogastric: pig, birds (chickens, laying hens)
- ✓ Fish
- ✓ Insects (insects as food, bees)

Ruminants and monogastrics represent the majority of animals of zootechnical interest

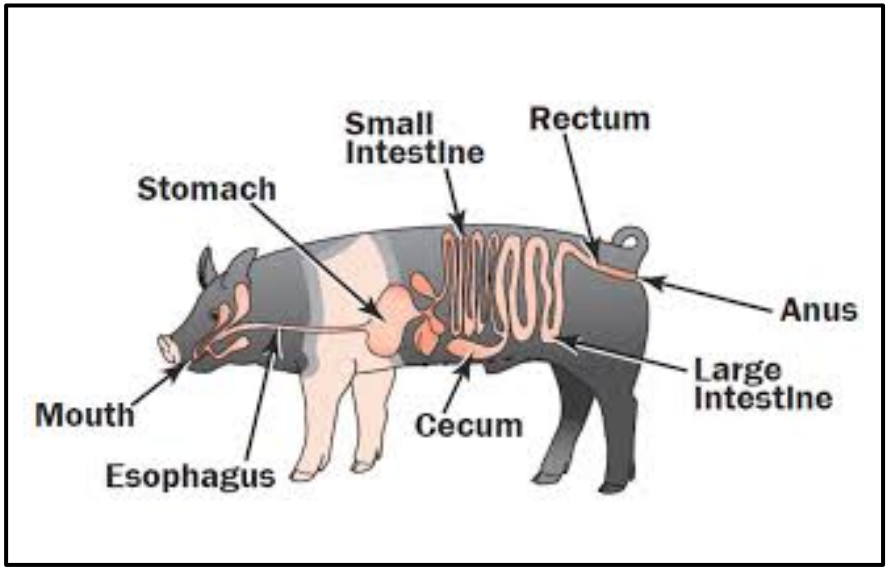
What is the main difference between them?

Ruminant digestive tract



©1999 Addison Wesley Longman, Inc.

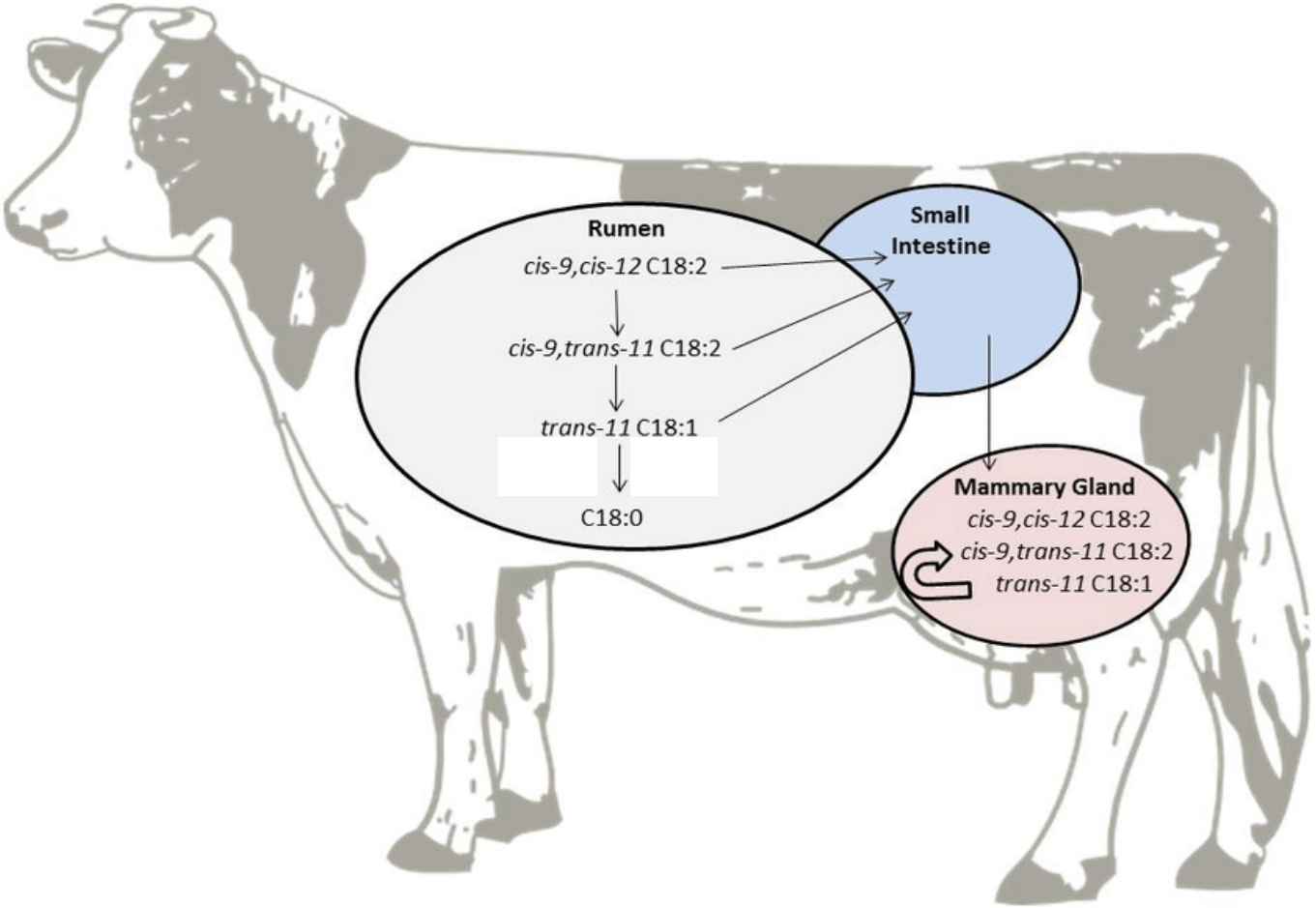
Monogastric digestive tract



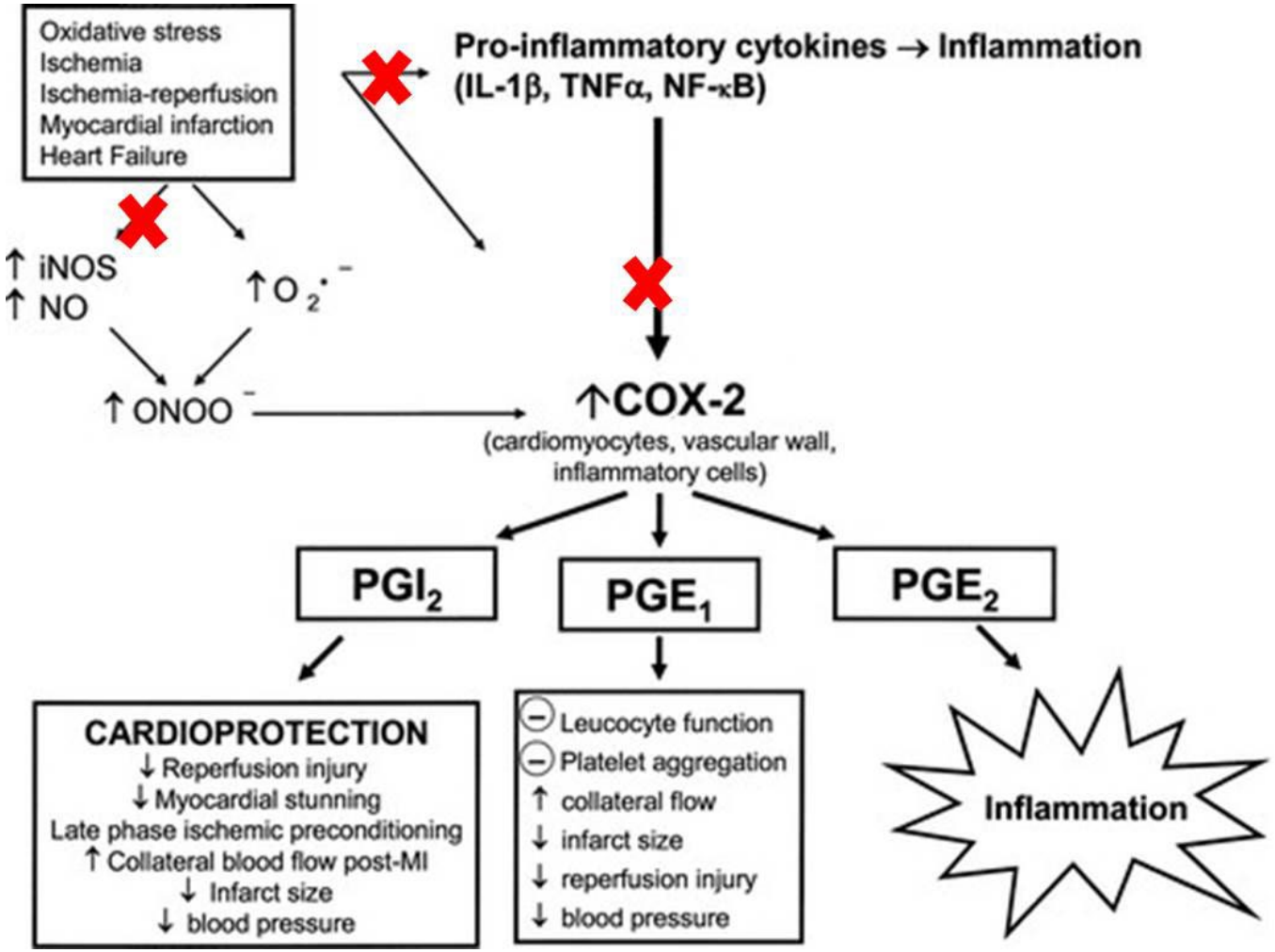
How the ruminal function influences the production quality?

Biohydrogenation

Ruminal Biohydrogenation



Bassaganya-Riera, J., & Hontecillas, R. (2010). Dietary CLA and n-3 PUFA in inflammatory bowel disease. Current opinion in clinical nutrition and metabolic care, 13(5), 569.
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2947030/pdf/nihms237437.pdf



Production systems

Intensive *vs* Extensive

Intensive production systems

- ✓ **Indoor breeding – Animals live and are fed inside facilities dedicated to breeding**
- ✓ **Many of these systems are also essentially "landless"**
- ✓ **High genetic merit, high density, high cares, high technology, high energy.**

High production

Extensive production systems

- ✓ Outdoors/free range
- ✓ Mainly self feeding
- ✓ Low genetic merit (the main intent is not to select the most suitable for production)
- ✓ Keep biodiversity
- ✓ Low density
- ✓ Low cares
- ✓ Low energy
- ✓ Low technology
- ✓ Low production

Organic production

Animals must be born and raised on organic farms

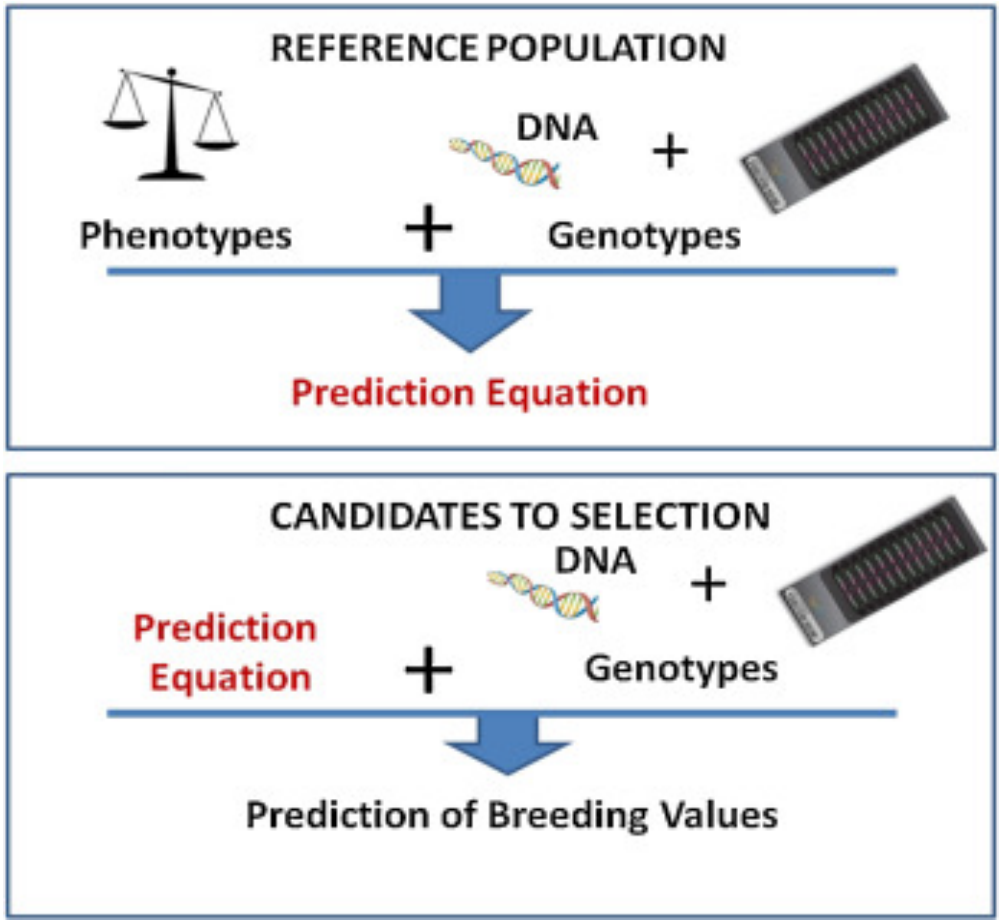
- ✓ **Practices and housing**: number of livestock per unit of land must be limited; animals should have, whenever possible, access to open air or grazing areas.
- ✓ **Breeding**: natural methods must be used. Artificial insemination is however allowed; hormones are not permitted, unless as a form of veterinary therapeutic treatment.
- ✓ **Feed:** should primarily be obtained in the farm where the animals are kept or from farms in the same region; should be 100% organic feed; growth promoters and synthetic amino-acids are prohibited; suckling mammals must be fed with natural, preferably maternal milk.
- ✓ **Diseases and cares**: Farmers can prevent diseases by selecting the appropriate breed. When the animals are ill, chemically synthesized allopathic veterinary medicinal products including antibiotics may be used where necessary and under strict conditions. This is only allowed when the use of phytotherapeutic, homeopathic and other products is inappropriate.

Genetic selection

- ✓ Generally used in intensive systems but also adopted for the selection of breeds capable of better adapting to free range conditions (outdoors).
- ✓ Is a technical to improve production and reproduction in livestock through the evaluation and subsequent choice (selection) of the reproducers.
- ✓ Variability in the population is necessary for selection it generates permanent increase of production
- ✓ Different parameters are selected
- ✓ Genomic selection is the new approach (combine analysis on DNA and phenotype information)

Genomic selection is the new approach

- ✓ Genomic selection is based on estimation of detailed associations between a very dense set of genetic markers (SNP) and phenotypes on a selected group of animals
- ✓ The resulting prediction equations are then applied to SNP genotypes of the rest of the population to estimate their genomic breeding, without the need of additional phenotypes.



Principles of genomic selection. Top: a prediction equation is obtained from a reference population with phenotypes and genotypes; bottom: this prediction equation is used on candidates with genotypic information only.

What does is selected?

- ✓ **Production traits**: Milk, protein and fat
- ✓ **Yield**: weight gain, feed conversion efficiency, quantity of the obtained product
- ✓ **Morphological traits**: udder (dairy ruminants), foot
- ✓ **Functional traits**: reproductive and longevity indices

The first two points are mainly related to intensive systems since particular attention is given to the animal ability to obtain high production yield in a short period of time.
The last two points can also be considered of interest for animals reared in extensive systems, as morphological and functional aspects are also taken into consideration which may justify a better adaptation of the animal in outdoor farming conditions.

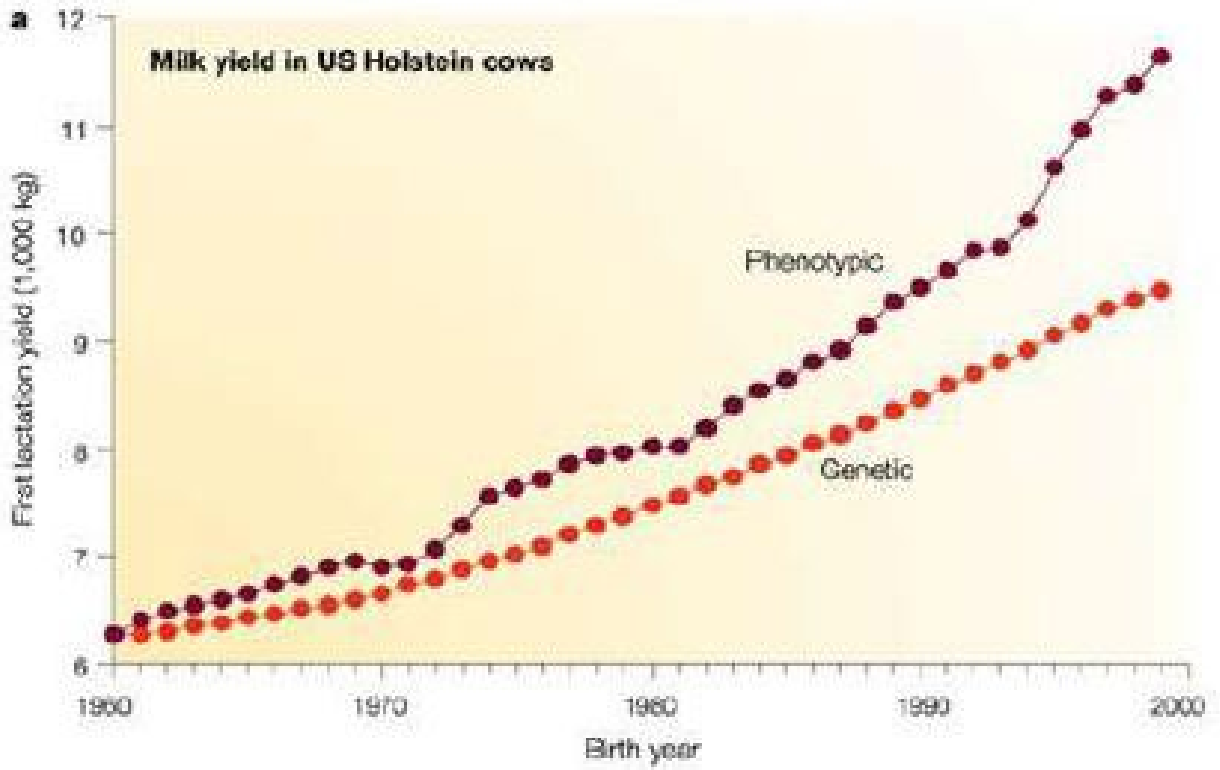
The importance of genomic selection

Using nuclear science to improve animal breeding
https://www.youtube.com/watch?v=3kIAGwHSsns

What are Estimated Breeding Values?
https://www.youtube.com/watch?v=Yhsw3HJDtf4

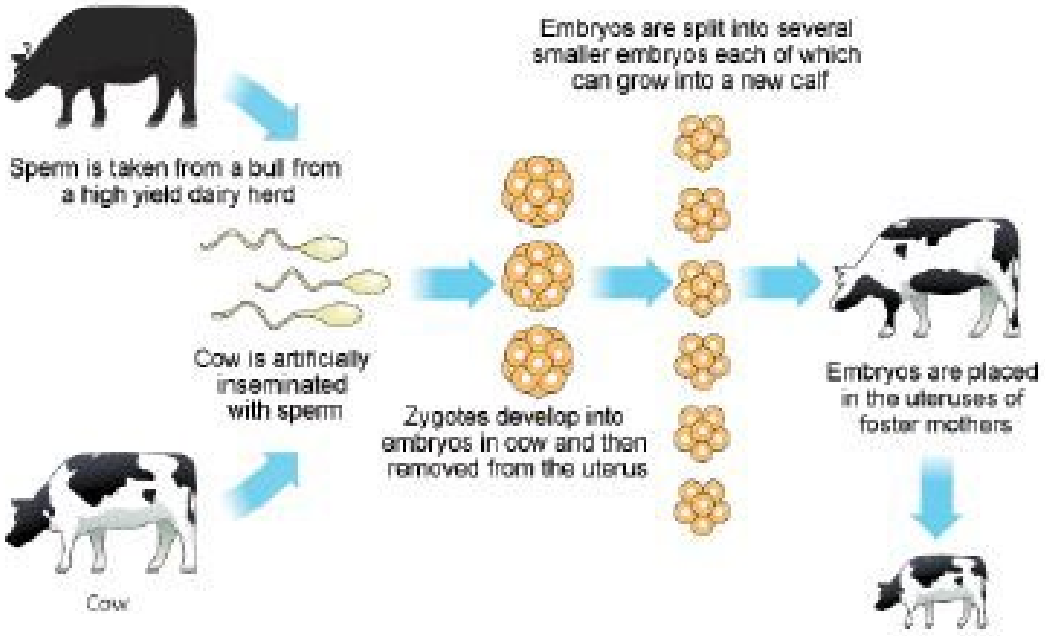
Critical Discussion
www.youtube.com/watch?v=i6crfeC6VbA

Some results of genetic selection

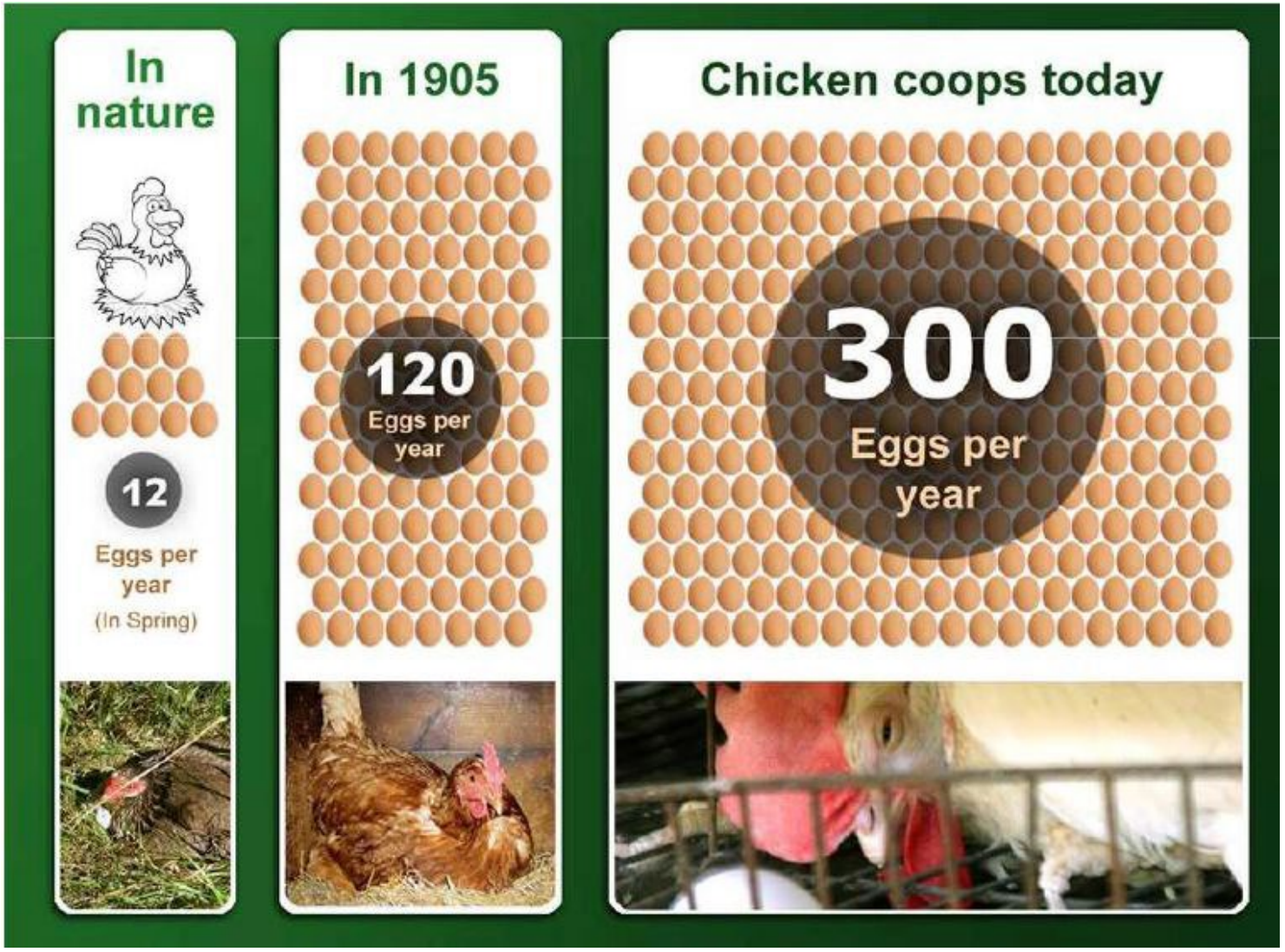


Embryo transfer

Removal of embryos from high genetic merit cow (donor) and placement into a surrogate cow with low genetic merit or even in a different breed (recipient) for differentiation, growth and birth.



The role of genetic selection in eggs production



Laying Hens
Intensive vs Organic system

	Intensive (battery cage)	Intensive onshore	organic Free range
Laying age	20	20	20
End of cycle (weeks)	72	72	72
Lay length (weeks)	52	52	52
Mortality (%)	5	8	10
Eggs per cycle	280	286	267
Eggs declassed (%)	6	9	10
Feed consumed head/day (g)	115	120	130

(adapted from Pignattelli P. 2001)



Chicken meat production

Intensive *vs* Free range/Organic system

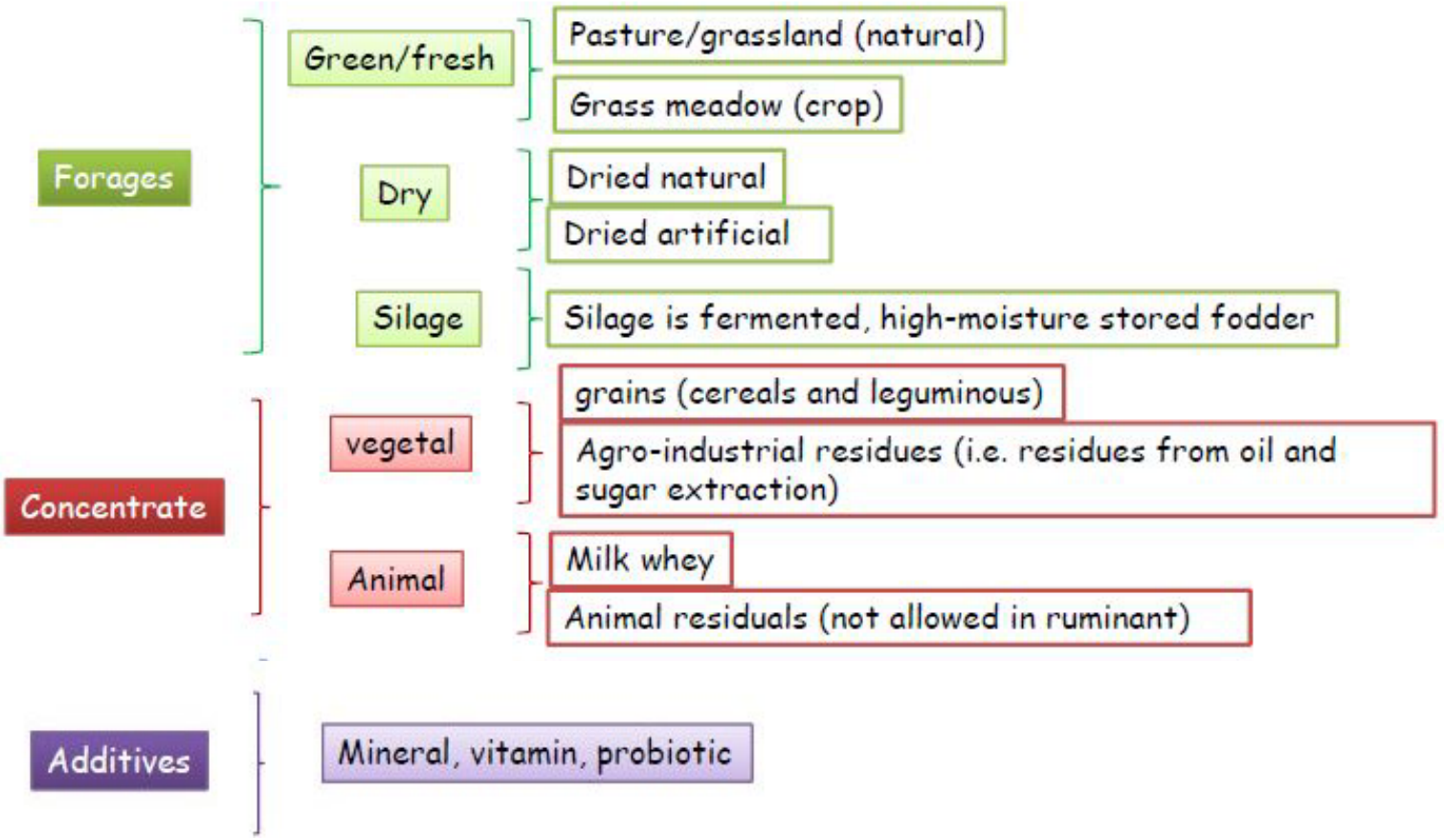
https://www.youtube.com/watch?v=mJEM3TUX-uU

Key aspects:

- ✓ **Farming density**
- ✓ **Exploitation of natural resources** (in organic systems there is an immediate exploitation of natural resources, while in intensive systems natural resources are used upstream for the production of services, such as electricity to be used in indoor structures).
- ✓ **Ethical issue** (the organic system appears more ethical as more freedom is granted to animals, but in case of disease it is not possible to use synthetic drugs as in the intensive systems so animals can undergo longer periods of suffering).
- ✓ **Product price**

In conclusion, each consumer makes his own assessments and chooses…

Feeds for Livestock



Forages

The forages used in livestock feed contain various components useful for the metabolic health of the animals.

The main components are: fibers (cellulose which represents an important source of carbohydrates), proteins, vitamins (both fat-soluble and water-soluble), microelements (especially divalent ions such as manganese and magnesium), and bioactive compounds (mainly phenolic compounds with antioxidant action).

Concentrate

They include those based on starch (cereal), fat (protected fat), protein (soy meal), rich in fiber (soy hull), rich in fiber and fat (Cotton seeds).
In addition they are commercial concentrate that can be a mix of them above.
Concentrate may be: raw, meal, pelleted, flaked, etc

Starch: It represents cereal and corn, it accounts 80% and 20% of diet for monogastric (pig and broiler) and dairy cattle, respectively. It is high energetic and digestible

Lipid: High energy but it can not be used up 5%. It can be oil (soy oil, palm oil), seeds (soy, cotton), and protected fat (absorbed intestine).

Protein: high protein content, the soy is the main used. It can be as seed and as meal after oil extraction. Its quality depends from protein content, ratio of the protein rumen degradable and rumen by-pass, and essential amino acid concentration.

Additives

Additives or supplements are substance that not have a nutritive value but their use may improve feed security, feed efficiency, feed acceptance, health and metabolism.

Stability and security of feed: mold inhibitor used to contrast mold development in feed, or they may be substances that have antioxidant (oxidation fat) action such as vitamin C and E.

Buffers: are salt used to balance pH of rumen, for example they may buffer acidosis at the beginning of lactation when cows are feed with high concentrate diet.

Flavors: are additives used to increase palatability and feed intake

Additives

Probiotics: are "live micro-organisms which, when administered in adequate amounts, confer a health benefit on the host". (World Health Organization, 2001). The main are: *Lactobacillus acidophilus, Lactobacillus casei, Lactococcus lactis, Enterococcus faecium, Bifidobacterium bifidum, Bifidobacteriumt hermophilum*, and *Saccharomyces cerevisiae*.

They maintain proper composition of intestinal microflora, have a positive effect on immune system increasing the IgA release or macrophage activity.

Additives

Organic Acids: are naturally present in plants, in animal tissues, and are also produced in the gut starting from the fermentation of carbohydrates. Short chain organic acids have antimicrobial capacity such as formic acid, acetic, propionic, butyric, lactic, sorbic, fumaric, tartaric, citric and benzoic acid. Their mechanism of action includes lowering the pH of the stomach, increase the proteolytic action and the digestibility of foods, increased pancreatic secretion, control the bacterial population by promoting the growth of useful bacteria and decreasing pathogen bacteria

Additives

Phytotherapics: are natural secondary compounds of plants and their use in livestock is increasing. It is reported a positive effects on the production and animal health. Studies have shown that the use of these extracts in the diet of livestock species induces improvements in production performance, feed conversion, antioxidant capacity of plasma, rumen activity and intestinal enzyme activity.

Very important in the organic farming systems!

Reproduction

- ✓ **High technology**: oestrus synchronization (in order to synchronize lactation), instrumental insemination (artificial insemination), sexed semen (when necessary), embryo transfer (optional)
- ✓ **Management of reproduction**: Ovulation may be synchronized with hormonal treatments. Artificial insemination is done in correspondence of the ovulation induced, when females are ready to be fertilized.

Species distribution and production systems

Dairy Cows bred in Italy

Breed	Yield/lactation	Protein %	Fat %
Holstein	9,325	3.25	3.67
Brown Swiss	7,095	3.52	4.00
Simmental	6,592	3.39	3.88
Jersey	6,116	3.89	4.88
Reggiana	5,416	3.37	3.69

Cosmopolites breeds

The most common are: Charolaise, Limousine, Angus black or red.

- ✓ They are high selected and have a good fecundity, high growth rate, high feed conversion index and high yield

Charolaise

Limousine

Angus Black

Italian breeds

They are characterized by white coat and distributed in northwest, central and south Italy.

- ✓ Piemontese, Chianina, Marchigiana, Romagnola, Maremmana and Podolica.
- ✓ They are low selected and less productive than cosmopolitan one

Piemontese

Chianina

Maremmana

Feedlot beef

A feedlot is a in intensive animal farming for finishing beef cattle. Calves are buy from cow-calf farms at age of 6-10 months and then fattened until slaughter weight.

- ✓ They are confined in a quarters with the scope to put weight as quickly as possible
- ✓ High concentrated diet (20:80)

How a Feedlot Works

https://www.youtube.com/watch?v=E_-pNVP4XjM

Key aspects:

- High genetic merit (standardized production)
- High technology for feed and fresh water distribution
- The main issue is related to the animal density, with consequent effects on animal welfare…

Main dairy sheep breeds reared in Italy

Sarda (Sardinia)

Massese (Tuscany)

Comisana (Sicily)

Main Dairy goat breeds reared in Italy

Saanen - imported from Switzerland and spread throughout Italy

Maltese - coming from Asia and widespread especially in southern Italy

Camosciata delle Alpi - imported from Switzerland and widespread especially in the nothern Italy

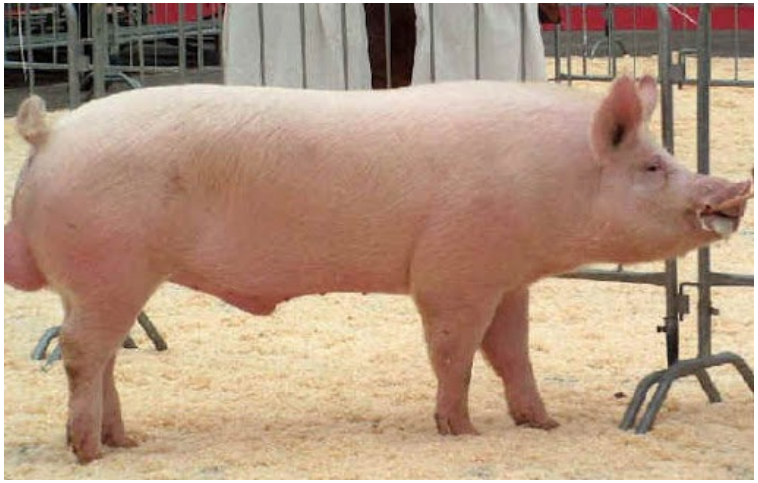
Some breeds raised in Italy for meat production

Appenninica -widespread especially in the middle of Italy

Sopravissana -widespread especially in the middle of Italy

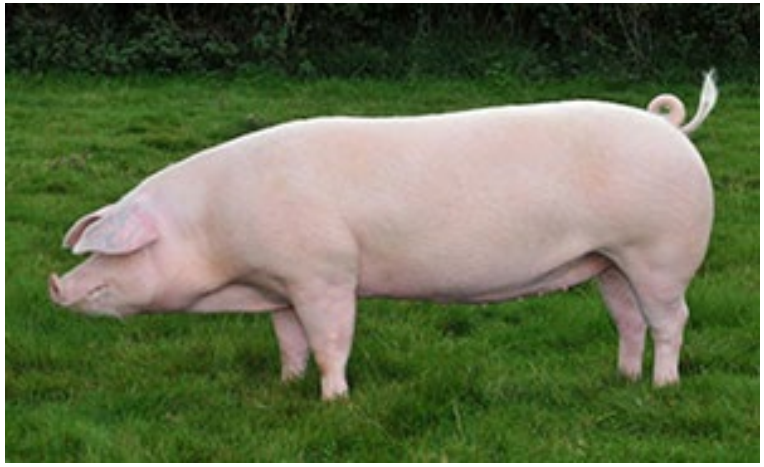
Suffolk - imported from Great Britain and widespread especially in the nothern Italy

Main breeds raised in Italy



Large White

Duroc



Landrace

Main Italian breeds

Cinta senese (Tuscany)

Mora Romagnola
(Emilia Romagna)

Casertana
(Campania)

Broiler

Broilers are bred to produce meat. The system is based on breeding and fattening stages.

- ✓ The breeding is composed of two stage: production of parents and multiplication of broilers to be fattened
- ✓ The finishing stage is based on the fattening of broiler

They can be farmed as intensive, extensive or organic system

Broiler
Conventional *vs* Organic system

Parameters	Conventional	Organic
Slaughter weight (kg)	2.4	2.2
N° cycles for year	4.7	3.5
N° broilers for cycle	44,000	4,000
Mortality for cycle	5.7	8.3
Feed conversion	2	3.2

Laying Hens

- ✓ In the same farm is possible to have the breeding step (production of hens) and production (laying eggs deposition)
- ✓ Deposition starts at 16-20 weeks old and continues for 12 months, after hens are slaughtered
- ✓ Environmental conditions are often automatically controlled in egg-laying systems. Light is set up in order to mimic the summer day length
- ✓ Hen produces about 300 eggs for cycle
- ✓ They can be farmed as intensive, extensive or organic system

Bees

Bees are social insects belonging the *Hymenoptera* order. Domestic bees or honeybees, belong the specifies *Apis mellifera* L. The name "*Apis*" comes from the Latin language, and "*mellifera*" means "honey-bearing". The species differ from the others for the large amount of honey that can be stored.

The breeds of *Apis mellifera* are divided into 3 major groups: eastern breeds, african breeds and european breeds.

Among the european breeds:

- ✓ *Apis mellifera ligustica* Spinola, 1806, or Italian bee;
- ✓ *Apis mellifera sicula* Montagno, 1911, or Sicilian bee;
- ✓ *Apis mellifera mellifera* Linnaeus, 1758, or European black bee;
- ✓ *Apis mellifera Caucasian* Gorbachev, 1916, or Caucasian Bee;
- ✓ *Apis mellifera Iberian* Engel, 1999 or Spanish Bee;
- ✓ *Apis mellifera cypria* Pollmann, 1879;
- ✓ Apis mellifera cecropia Kiesenwetter, 1860, or Greek Bee.

Bees

The management of a beehive mainly consists in monitoring its development according to the period and environmental conditions.

A bee colony consists of a single queen, many workers (sterile females), a small number of drones (males) and the brood (larvae). A beehive is made up of a single colony or family.

Bees

To reproduce and survive, a colony of bees tries to accumulate the maximum possible supplies during the good season, in order to spend the winter.

The population of the colony changes according to the seasons. It is very large in periods when natural resources are abundant (from 30,000 to 70,000 individuals), in order to make the largest possible collection. In winter it decreases to around 6,000 individuals, to reduce the consumption of supplies to the minimum.

However, the population cannot go beyond a certain limit, since it is the one that must maintain the temperature inside the hive and will have to relaunch the colony in spring.

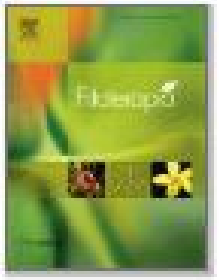
Hive products

- Honey
- Royal jelly
- Pollen
- Propolis
- Poison
- Wax

Propolis

ELSEVIER

Fitoterapia
Volume 73, Supplement 1, November 2002, Pages S53-S63



Phytochemical compounds involved in the anti-inflammatory effect of propolis extract

F. Borrelli [a], P. Maffia [a], L. Pinto [a], A. Ianaro [a], A. Russo [b], F. Capasso [a], A. Ialenti [a]

Several bioactive compounds in propolis (mainly polyphenols) are reported to induce health benefits for humans

The main enemies of bees

- ✓ ***Varroa destructor***
- ✓ ***Acarapis woodi***
- ✓ **American foulbrood and European foulbrood**
- ✓ **Vespa Crabro and Velutina**
- ✓ **Wax moth**
- ✓ **Nosemiase**
- ✓ **Small hive beetle**

…The role of genetic selection

Biomonitoring: The term Biomonitoring refers to the assessment and trending of pollutant dynamics in a given ecosystem using living organisms.

Bioaccumulators: organisms able to survive in the presence of pollutants that accumulate in their tissues.

Bioindicators: organisms that undergo obvious changes in physiology, morphology or spatial distribution correlated with substances (pollutants, contaminants, etc.) present in that environment.

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Sustainable Livestock Production

The bioindicators alert us with overt or covert 'signals' of what has happened or is happening in a given ecosystem.
The biomonitoring is the ability to observe, organise and interpret these signals.

Long-term biomonitoring programmes not only increase scientific knowledge but also provide information for environmentalpolicies and should be considered fundamental components of economicpolicies.

The biomonitoring with bees is a well-established technique. Close interaction of the bee with environmental compartments. The knowledge of the chemical and physical characteristics of pollutants obliges the choice of the matrix in which to search for them.

The bees are bio-indicator? Yes, but how?

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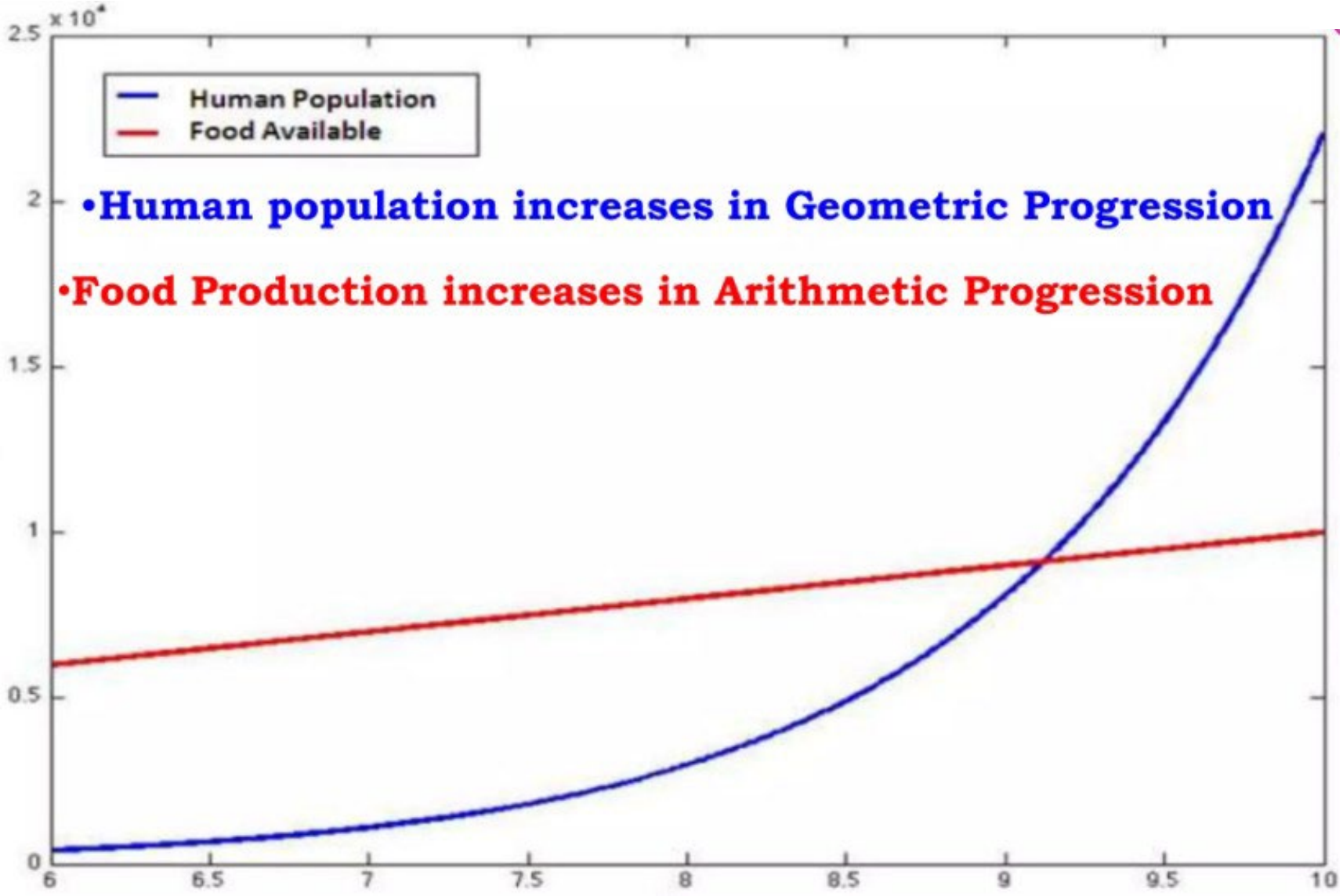
Sustainable Livestock Production

Pesticides, a heterogeneous group of non-volatile and persistent lipophilic substances, are environmental pollutants widely used in agriculture, households and animal husbandry. These molecules, hazardous to human and bee health, have a higher affinity for fatty matrices.

Among the possible analytical matrices present in the hive, **wax, which is mainly composed of hydrocarbons, fatty acids and wax acid esters, is ideal for the identification and quantification of pesticides in environmental bio-monitoring activities.**

However, gas and liquid chromatographic analysis is particularly complex for the determination of toxic residues in wax due to the presence of interfering lipid substances. (Korta *et al.* 2003, Niell *et al.* 2014).

Insects as food

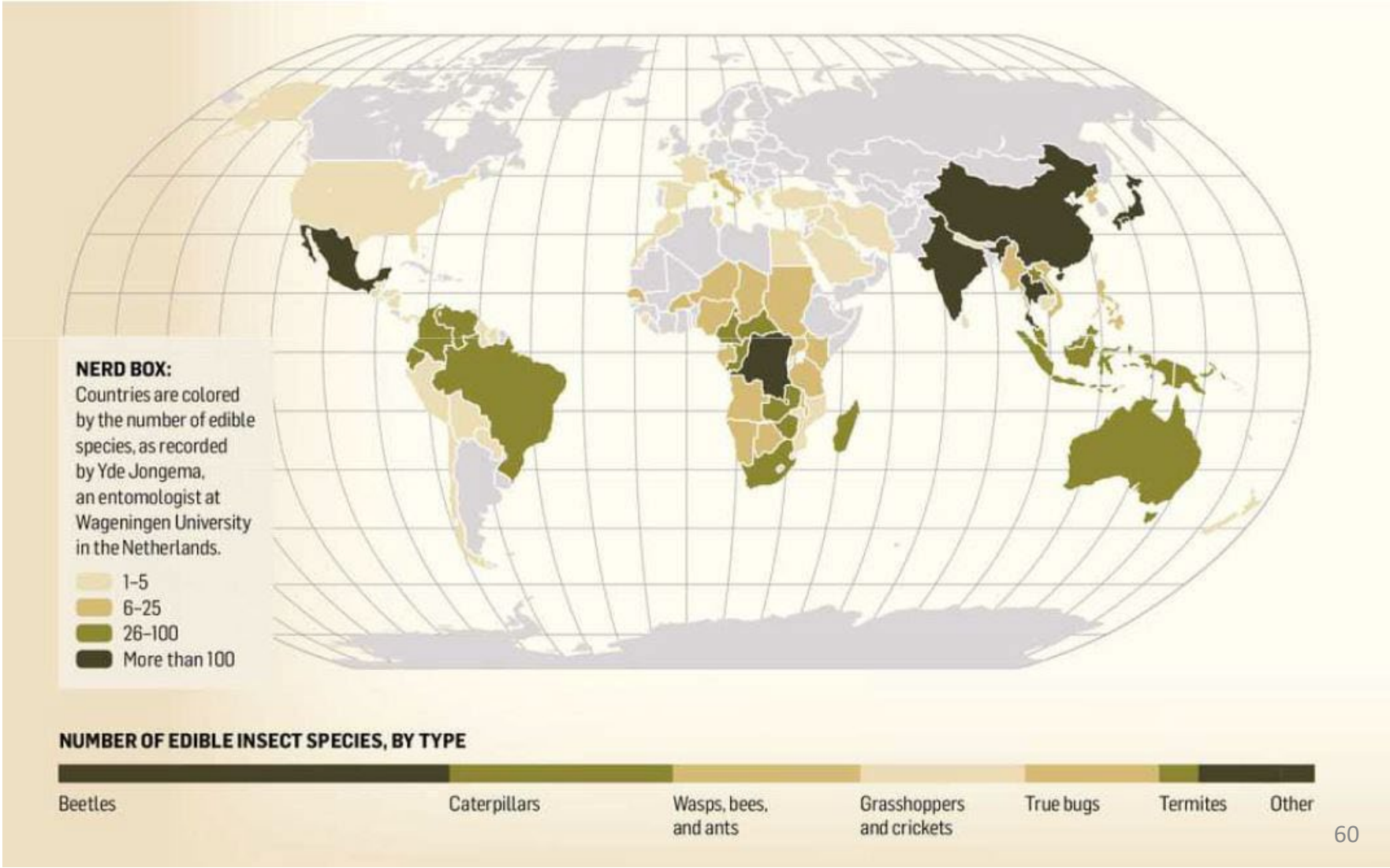

x 10^4
2.5
2
1.5
1
0.5
0
6
6.5
7
7.5
8
8.5
9
9.5
10
Human Population
Food Available
•Human population increases in Geometric Progression
•Food Production increases in Arithmetic Progression

WHY NOT EAT INSECTS?

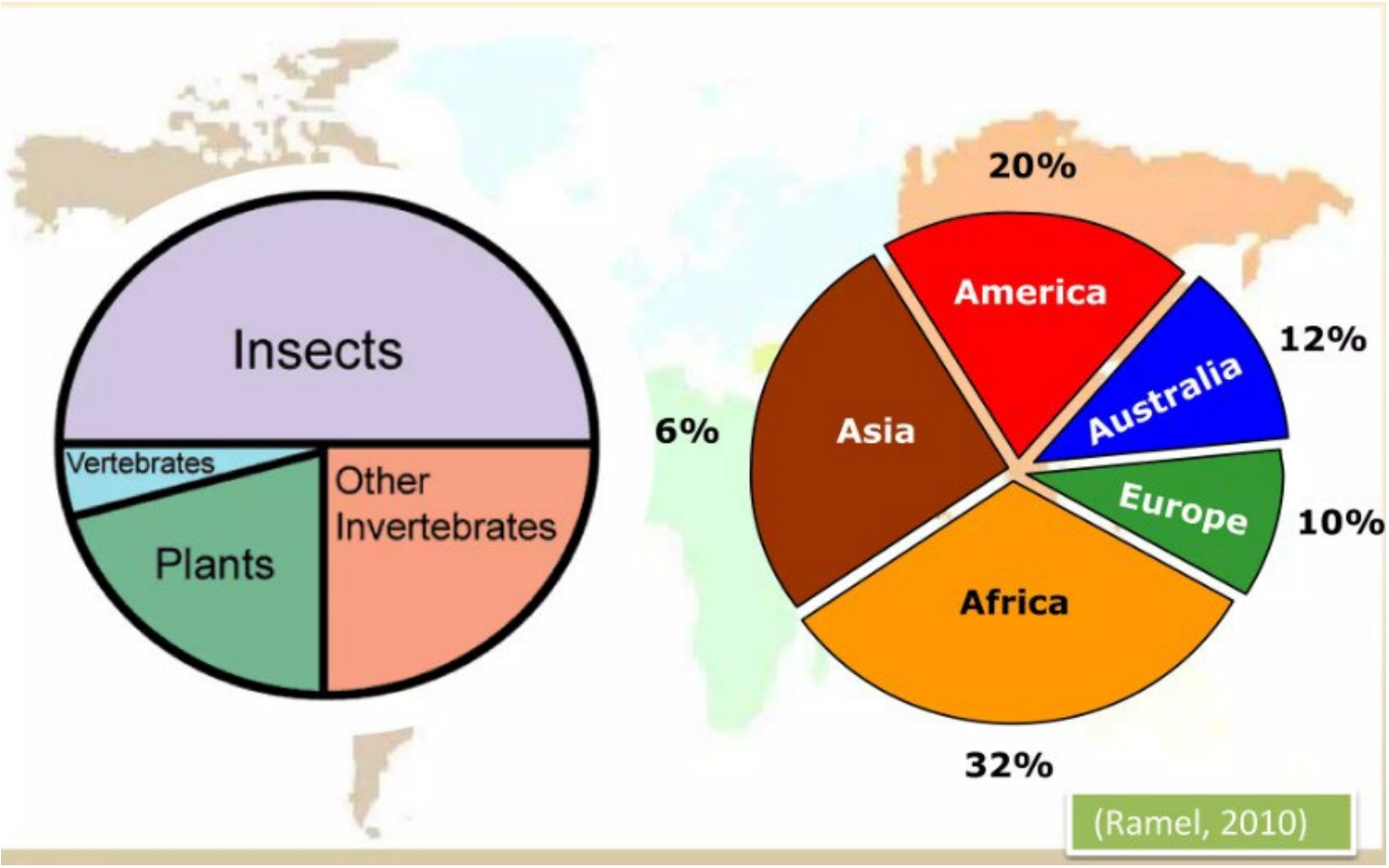
- In many countries, beef, chicken, and fish are not easy to procure .
- Insects are cheap, sustainable, tasty protein source
  - ✓ Lots of vitamins and minerals
  - ✓ Low in fat and cholesterol
- Many other insect are also eaten
- Lobsters, crabs, and shrimp
  - ✓ Scorpions
  - ✓ Spiders. **(Mary Hall , 2013)**

Eat more insects to fight hunger: UN

Insects as food



Insects population and consumption status in the World



Main properties of insects for food production

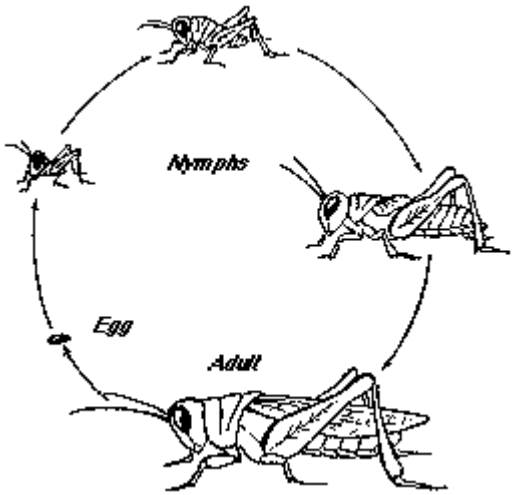
Insects are farmed since long time for honey, silk and other purpose

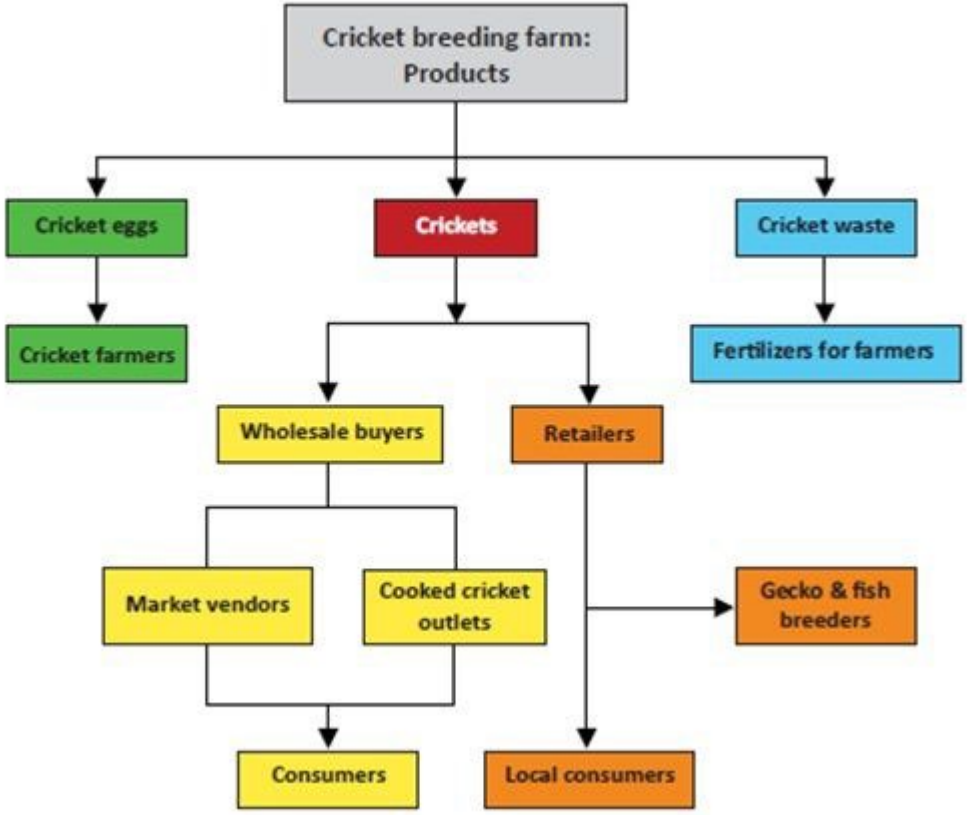
They are farmed also for food production

The species used for this purpose should be:

- ✓ Gregarious (living in a group)
- ✓ High growth rate
- ✓ Short cycle
- ✓ High % of laying
- ✓ High feed conversion factors
- ✓ Low vulnerability to diseases

Stages of insects farming





- ✓ **Reproduction stage**
- ✓ **Production stage**

Even in the case of insects these stages can coexist in the same structure

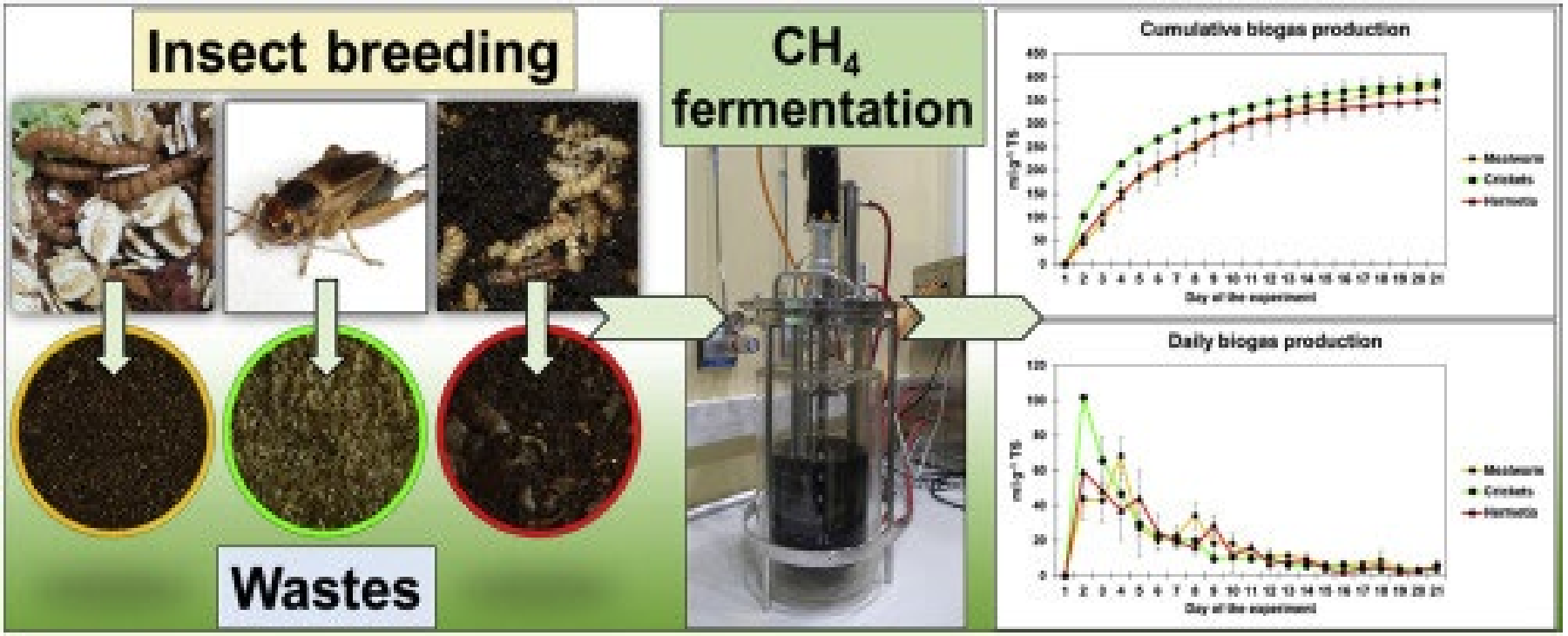
Insects breeding

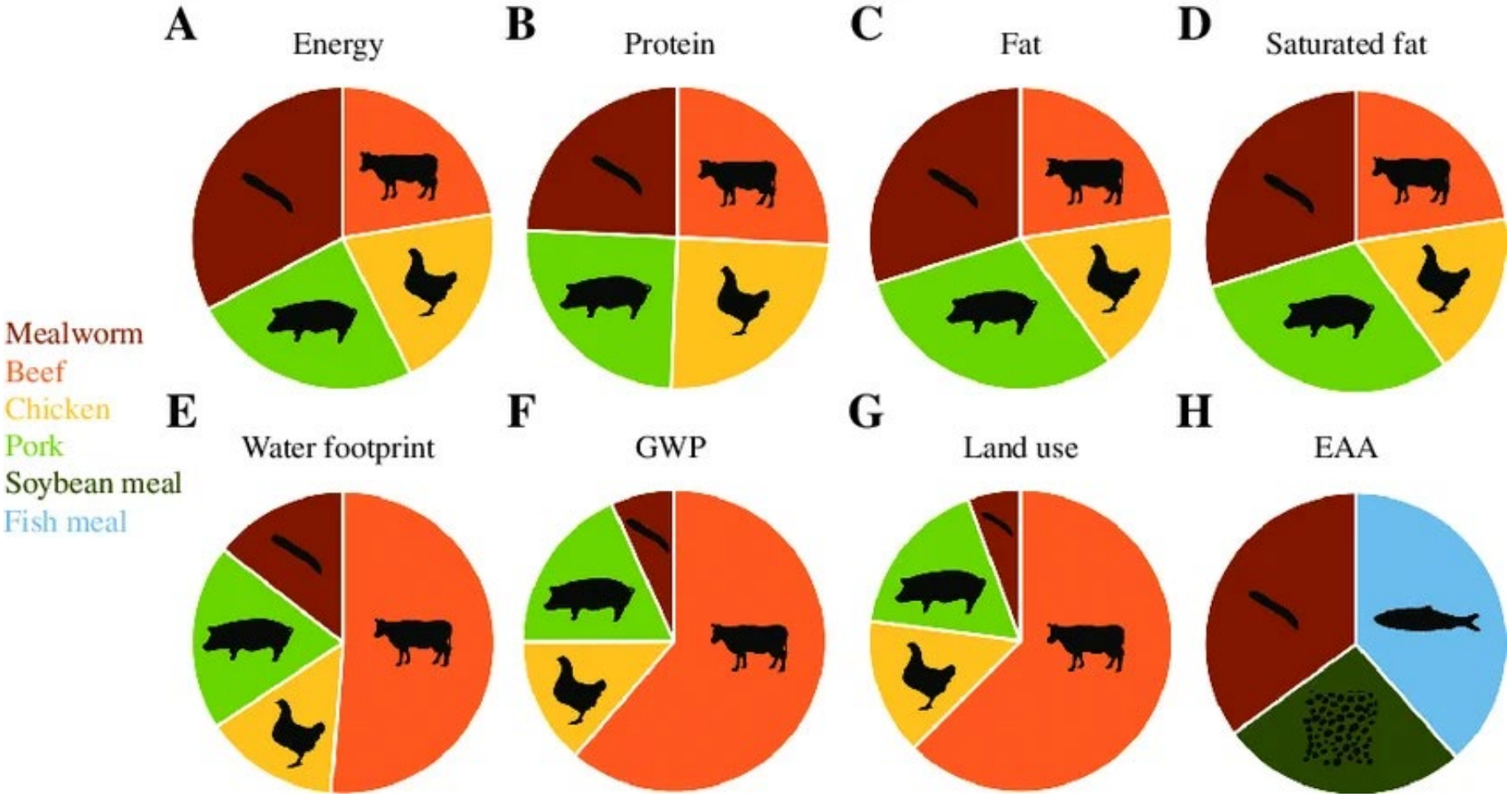
Breeding insects share similarities and differences with the breeding of larger animals.

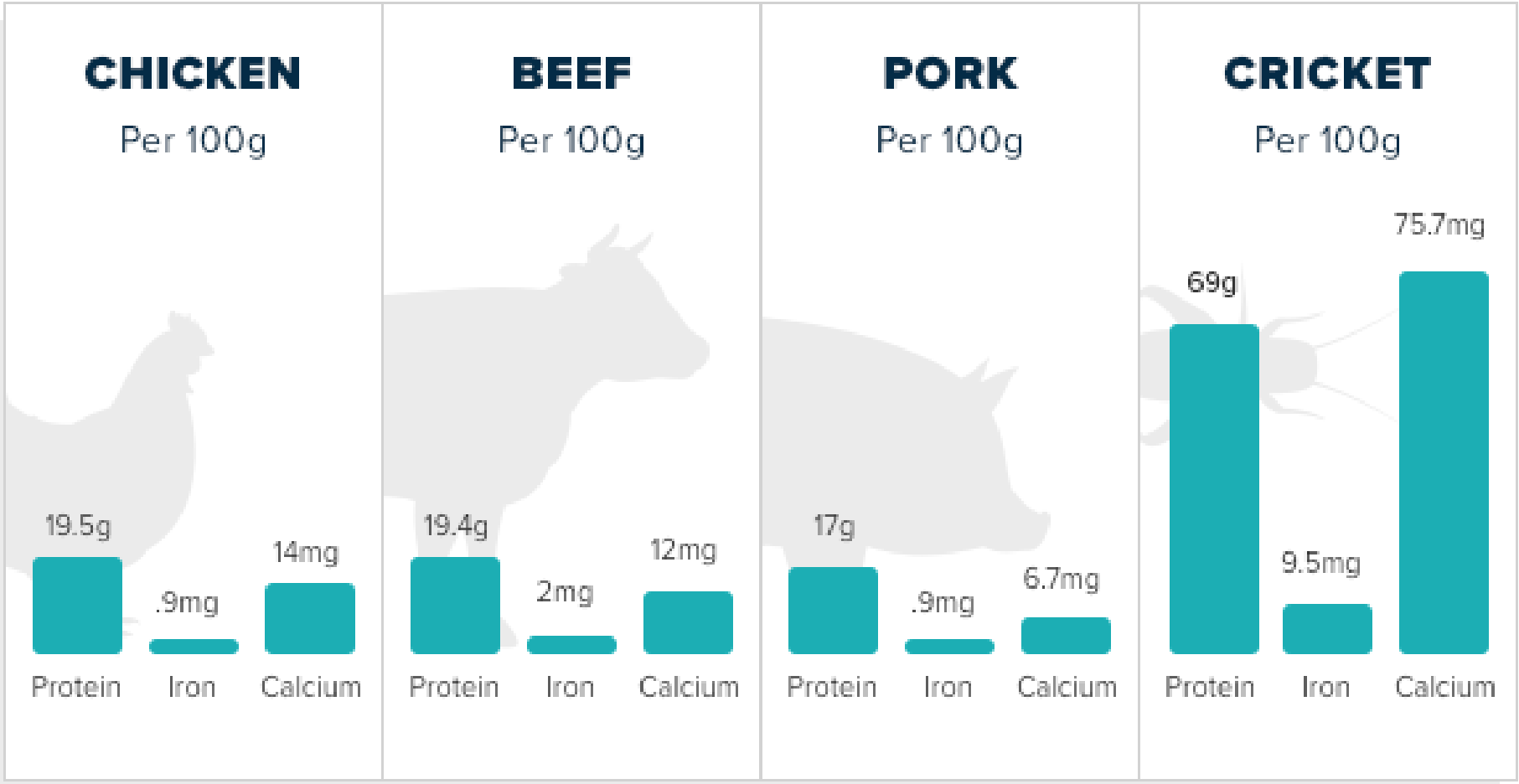
Due to the high amount of insect species, breeding techniques are mostly insect-specific.

Difficulties are also species specific.

Insects breeding




A
Energy
B
Protein
C
Fat
D
Saturated fat
Mealworm
Beef
Chicken
Pork
Soybean meal
Fish meal
E
Water footprint
F
GWP
G
Land use
H
EAA


CHICKEN
Per 100g
19.5g
.9mg
14mg
Protein
Iron
Calcium
BEEF
Per 100g
19.4g
2mg
12mg
Protein
Iron
Calcium
PORK
Per 100g
17g
.9mg
6.7mg
Protein
Iron
Calcium
CRICKET
Per 100g
69g
9.5mg
75.7mg
Protein
Iron
Calcium

Properties	Black Soldier Fly	Mealworm	Cricket
			
Crude protein (%)	41–43	48–57	58–69
Main amino acids	1. Aspartic acid 2. Glutamic acid 3.Valine	1. Glutamic acid 2. Leucine 3. Aspartic acid	1. Glutamic acid 2. Leucine 3. Alanine
Lipids (%)	17–34	32–40	11–23
Main fatty acids	1. Lauric acid 2. Oleic acid 3. Palmitic acid	1. Oleic acid 2. Linoleic Acid 3. Palmitic acid	1. Linoleic acid 2. Oleic Acid 3. Palmitic acid
Crude fiber (%)	4–10	2–5	6–8
Ash (%)	15–27	2–4	3–8
Gross energy (MJ/kg)	20–24	26–27	20–22
Calcium (g/kg)	58–93	1–5	5–15
Phosphorus (g/kg)	5–13	4–11	7–8

Did you know?

E120 (Cochineal) is a natural red colorant derived from insects, widely used to impart red, pink, or purple hues to food and cosmetics. Common applications include dairy products (yogurt), sweets, beverages, processed meats (sausages), jams, and cosmetics like lipstick.

Advantages

- Insects provide high-quality protein and nutrients compared with meat and fish.
- Insects are particularly important as a food supplement for undernourished children because most insect species are high in fatty acids (comparable with fish).
- They are also rich in micronutrients.
- Insects pose a low risk of transmitting zoonotic diseases
- New efforts and standards are required to assure nutritional quality and safety of insect foods.

Disadvantages

- Pesticide use can make insects unsuitable for human consumption
- Herbicides can accumulate in insects through bioaccumulation
- Cases of lead poisoning after consumption of chapulines were reported by the California Department of Health Services in November 2003
- Adverse allergic reactions are also a possible hazard

Can Bug Farming Solve World Hunger?

https://www.youtube.com/watch?v=quXiWq5XFPA